

(19)



Europäisches Patentamt
European Patent Office
Office européen des brevets



(11)

EP 0 740 822 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:
02.07.2003 Bulletin 2003/27

(21) Application number: **95910863.0**

(22) Date of filing: **19.01.1995**

(51) Int Cl.7: **G08B 13/24**

(86) International application number:
PCT/US95/00380

(87) International publication number:
WO 95/020205 (27.07.1995 Gazette 1995/32)

(54) **METAL DETECTION SYSTEM**

METALLDETEKTORSYSTEM

SYSTEME DE DETECTION DE METAUX

(84) Designated Contracting States:
**AT BE CH DE DK ES FR GB GR IE IT LI LU MC NL
PT SE**

(30) Priority: **19.01.1994 US 183696**

(43) Date of publication of application:
06.11.1996 Bulletin 1996/45

(73) Proprietor: **RANGER SECURITY DETECTORS,
INC.**
El Paso, TX 79925 (US)

(72) Inventors:
• **FRAHM, Steven, David**
El Paso, TX 79936 (US)

• **TURNER, John, Edward**
El Paso, TX 79936 (US)

(74) Representative: **UEXKÜLL & STOLBERG**
Patentanwälte
Beselerstrasse 4
22607 Hamburg (DE)

(56) References cited:
US-A- 3 697 972 **US-A- 3 758 849**
US-A- 3 896 371 **US-A- 4 293 816**
US-A- 4 486 712 **US-A- 5 039 981**

Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

Best Available Copy

EP 0 740 822 B1

Description

TECHNICAL FIELD

[0001] The present invention relates to metal detectors and, in particular, to an improved walk-through metal detection system.

BACKGROUND OF THE INVENTION

[0002] In recent years, walk-through metal detectors have become a commonly utilized piece of security equipment. While most people are familiar with, and accustomed to the use of such detection systems in airports, the state of society today has unfortunately necessitated the use of walk-through metal detection systems in such unconventional locations as schools and courthouses. Regardless of place of use, the primary continuing function of walk-through metal detection systems is to accurately detect the presence of hidden illicit metal objects such as firearms and knives on the body of an individual.

[0003] The operation of prior art walk-through detection systems for the purpose of detecting illicit metal objects, however, has been less than satisfactory in at least four ways. First, the detection electromagnetic field generated by prior art transmit-receive coils in walk-through detection systems is plagued by the presence of weak or "dead" spots through which a person may pass an illicit metal object without detection. Alternatively, the detector may be set to respond to objects in the weak or "dead" spots, but unfortunately this causes the detector to be hyper-sensitive in the areas with normal response to trigger undesired metal alarms. Second, the prior art electronic systems provided for processing the signals output from the transmit-receive coils lack the capability of discriminating between illicit and permissible metal objects. Thus, large metal buttons, pocket change and belt buckles are often identified, quite to the annoyance of the person being scanned, as illicit metal objects. Third, the prior art electronics systems for metal detectors have no provision for discriminating against the cumulative sum total metal mass of small, permissible metal objects versus the metal mass of a single, large, illicit metal object. This drawback is the largest source of undesired metal alarms, thus necessitating additional security personnel to perform time consuming searches. Fourth, the prior art electronic systems further lack the capability of approximately identifying on the body of an individual the location of the carried metal object triggering the alarm. Thus, security agents often require a near complete disrobing of the scanned individual to locate the offending metal object and determine whether the object is illicit.

[0004] Accordingly, there is a need for an improved walk-through metal detection system that provides for a more uniform generation of the detection electromagnetic field, is capable of discriminating between illicit and

permissible metal objects, is capable of discriminating between cumulative and lumped metal mass, and is capable of identifying the approximate location of the carried metal object triggering the alarm.

5 [0005] US-A-3,758,849 discloses a balanced field metal detector apparatus comprising a coil assembly including planar, generally rectangular loop configured multi-turn field and sensor coils disposed in partially overlapping minimum mutual inductive coupling relation
10 and oriented so that the long dimension of the loops is skewed relative to the vertical in use of the apparatus. It does not disclose the technical advantages of a metal detection system having a plurality of receiver coils connected in a one-to-one correspondent to a plurality of
15 detector circuits that output detection signals to a processor for generating a mass signal indicative of the total mass of a metal object disrupting an electromagnetic field.

[0006] US-A-4,486,712 discloses a metal detector apparatus particularly adapted as a locator of small, usually obscure, isolated objects such as treasure items, antipersonnel mines, weapons, shrapnel, and other such items. The detector is of the portable transmitter-receiver type having a dual balanced receiving
20 loop, together with a transmitter loop co-balanced relative with the receiving loop arrangement, whereby the unique loop sensing setup, together with a dual channel receiver, provides a separate "right" and "left" bearing indication to the operator of the obscure object's whereabouts. The imbalance between the normally balanced
25 loop arrangement electromagnetic fields, brought about by the nearby presence of a metallic object acts to produce a relative indicative difference in each receiving channel which provides the bearing, while the relative combined indication magnitude gives an indication of
30 proximate distance between the detector and the sought object.

[0007] US-A-3,896,371 discloses a a metal detector for detecting concealed metal objects such as coins. The discriminating circuit includes an L/C circuit which is forced to resonate at a frequency significantly higher
40 than its natural resonance frequency. This L/C circuit is adapted to provide an output signal having different amplitudes depending on the type of metal object which is in the proximity of the L/C circuit.

[0008] US-A-3,697,972 discloses a metal detection alarm system for detecting the presence of an article of a particular metal in a given region by measuring the disturbance of two oscillating electromagnetic fields,
50 one oscillating at from 5 to 20 kHz., the other at from 16 Hz. to 5 kHz., and also of the disturbance of a magnetic field established by D.C. pulses produced at a rate of 0 to 16 pulses per second.

[0009] US-A-4,293,816 discloses a search loop for a metal detector is described having a magnetic flux feedback coil whose magnetic flux opposes that of the transmit coil to provide a balanced loop. The balanced loop is thereby nulled and produces no output signal on the

receive coil when such loop is positioned in air remote from the ground and no metal object is present. The transmit coil, the feedback coil and the receive coil are supported coplanar with each other and the feedback coil is supported on the receive coil so that it is concentric therewith.

[0010] US-A-5,039,981 discloses structure and detection methods for electromagnetic field ferromagnetic security detection stations of the type conventionally used at airports and the like. Improved sensitivity to ferromagnetic masses, such as knives or firearms carried by a person in the vicinity of the feet, ankles or lower legs is achieved by interposing a riser platform to assure that the person is introduced into the detection electromagnetic field above the floor or ground plane a predetermined distance that increases sensitivity of the detection of ferromagnetic masses carried by the person in the lower part of the body.

SUMMARY OF THE INVENTION

[0011] In accordance with the present invention, a unique configuration of the transmit-receive coil for a walk-through metal detector is provided as claimed in claim 1. The transmit coil comprises a single coil of wire split in half and excited in phase, with one half of the split coil positioned on either side of a passageway for the walk-through metal detection system. Positioned adjacent each half of the split transmit coil is a separate receive coil. The combined transmit-receive coil is configured with a vertically elongated geometry. Due to mutual coupling between the split transmit coils, an electromagnetic field having a substantially uniform vertical field density (i.e., virtually no weak or "dead" spots) is generated, the field concentrated in the passageway. With a uniform vertical field, accurate detection of metal objects may be made regardless of relative position within the passageway.

[0012] The electronic system for the walk-through metal detection system of the present invention includes a separate detector circuit connected to each receive coil. The signals output from the detector circuits are processed to generate an output signal indicative of the total metal mass detected within the generated electromagnetic field. The output signal is compared to a threshold signal, and if greater than the threshold signal, an illicit metal object is presumed to be present within the electromagnetic field and an alarm is sounded. The use of separate detectors provides maximum sensitivity for discriminating between illicit and permissible metal objects by providing a response to an accurate approximation of true metal mass. Approximate horizontal position of the detected metal object may also be determined.

[0013] In accordance with another embodiment of the present invention, each receive coil on either side of the passageway comprises a plurality of individual receive coils. Each individual receive coil in the plurality of coils

is connected to a separate detector circuit outputting a complex phase and amplitude signal indicative of the detection of metal object(s) within the electromagnetic field. Each of the plurality of phase amplitude signals are converted to digital signals and processed using digital signal processing techniques to identify the metal object(s) disrupting the electromagnetic field. The use of dual multiple receive coils with digital signal processing facilitates not only the discrimination between illicit and permissible metal objects by determining individual lumped metal mass, but also the determination of the both the approximate vertical and horizontal position of the metal object detected in the field.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] A more complete understanding of the metal detection system of the present invention may be had by reference to the following recalled Description when taken in conjunction with the accompanying Drawings wherein:

FIGURE 1 is a block diagram of a first embodiment of the metal detection system of the present invention;

FIGURE 2 is a more detailed block diagram of the first embodiment of the system shown in FIGURE 1; FIGURE 3 illustrates the geometry of one of the transmit-receive coils in the first embodiment of the metal detection system shown in FIGURE 2;

FIGURE 4 is a block diagram of a second embodiment of the metal detection system of the present invention;

FIGURE 5 is a block diagram of the detector circuit for the system of FIGURE 4;

FIGURE 6 illustrates the geometry of one of the transmit-receive coils in the second embodiment of the metal detection system shown in FIGURE 4;

FIGURE 7 is a circuit diagram for the dual rate, high pass filter for the system of FIGURES 1 and 2;

FIGURE 8 is a circuit diagram for one of the chained logarithmic amplifier circuit with auto-zeroing for the system of FIGURES 1 and 2; and

FIGURE 9 is a circuit diagram for dual signal, dual rate, high pass filter for the system of FIGURES 4 and 5.

DETAILED DESCRIPTION OF THE DRAWINGS

[0015] Referring now to FIGURE 1, there is shown a block diagram of a first embodiment of the metal detection system 10 of the present invention. The system 10 utilizes a pair of multiple turn, very low frequency coil sets 11 positioned on either side of a passageway 26 through which persons or articles pass for scanning and detection of illicit metal objects. The system 10 utilizes a field generation coil 12 divided between the coil sets 11 and connected to a single oscillator circuit 14. The

single coil of wire for the field generation coil 12 is split at its mid-point 16 into a right coil 12r for one coil set 11r and a left coil 12l for the other coil set 11l. The split coils are connected in parallel, with the mid-point 16 coupled to one alternating current port 18 of the oscillator 14 and the ends 20 connected together and to another alternating current port 22. The right and left field generation coils 12r and 12l are excited in phase by the oscillator 14 to generate a single alternating current electromagnetic field 24 concentrated with substantially uniform field density in the passageway 26.

[0016] The presence of metal objects in the passageway 26, causes a disturbance in the electromagnetic field 24 generated by the co-phased field generation coils 12. This disturbance is sensed by dual, right and left receive coils 28r and 28l, respectively, that, like the split transmit coil 12, are also positioned in the coil sets 11r and 11l on opposite sides of the passageway 26. Each receive coil 28 in a coil set 11 is connected to a corresponding detector circuit 30 that detects the field disturbance. A processor 32 takes the approximate cube roots of the signal outputs from the detector circuits 30, redundantly multiplies and cross-differentiates the cube roots, and selects the lesser result (weaker signal) as an analog approximation of the total mass of the metal object(s) detected in the passageway 26. If the determined metal mass exceeds a predetermined threshold mass level, then an alarm 34 is sounded indicating the presence and detection of an illicit metal object. Although the preferred embodiment of the detector circuit 30 and processor 32 comprises analog circuit devices, it will, of course, be understood that the requisite detection and processing functions may be implemented using digital signal processing techniques as well.

[0017] Reference is now made to FIGURE 2, wherein there is shown a more detailed block diagram of the first embodiment of the metal detection system 10 of FIGURE 1. A channel selector circuit 36 is connected to the oscillator 14 to allow for the selection (signal CS) by the system user of different frequencies (preferably approximately 6 kilohertz, with 100 hertz separating the channels) for the generated alternating current electromagnetic field 24. Slight phase adjustments in the generated alternating current signal are also possible with the selector circuit 36. With proper frequency and phase selection, multiple systems 10 are operable in close proximity to each other with minimal interference to adversely affect performance. The oscillator 14 further includes two square wave outputs 38 and 40. The first output 38 provides a square wave in phase (signal I) with the generated electromagnetic field 24. The second output 40 provides a square wave in quadrature phase (signal Q) with the signal exciting the generated electromagnetic field 24.

[0018] Although illustrated in FIGURE 1 as a single coil, each side of the field generation coil 12 in a coil set 11 is preferably comprised of three separate elements. The first element is a transmit coil 42r and 42l, the sec-

ond element is a null adjust loop 44r and 44l, and the third element is a feedback coil 46r and 46l. The three elements of the field generation coil 12 in each coil set 11 are connected in series between the mid-point 16 and the coil end 20.

[0019] Reference is now made to FIGURE 3 wherein there is shown the geometry of one coil set 11 positioned on one side of the passageway 26. It will, of course, be understood that a mirror image of the coil geometry illustrated in FIGURE 3 is present in the coil set 11 on the opposite side of the passageway 26.

[0020] The transmit coil 42 for the field generation coil 12 has rounded corners and an elongated rectangular shape having a longitudinal axis 43 of symmetry. The null adjust loop 44 is coaxially aligned with the transmit coil 42 having a similar elongated rectangular shape with rounded corners. The null adjust loop 44 has a narrower width and a slightly shorter length than the transmit coil 42. The feedback coil 46 is co-planar with and also coaxially aligned with the transmit coil 42, and is co-located with and has a substantially identical overall size and shape as the null adjust loop 44. Similarly, the receive coil 28 is also co-planar and coaxially aligned with the transmit coil 42, and is co-located with and has a substantially identical overall size and shape as the null adjust loop 44 and feedback coil 46.

[0021] The transmit coil 42 is shielded with a resistive Faraday split section tubular shield 45 that is terminated to system ground 49. The co-located receive coil 28 and feedback coil 46 are gathered together and also shielded with a resistive Faraday split section tubular shield 47 that is terminated to system ground 49. Termination of the shields 45 and 47 to system ground provides primary electromechanical interference and radio frequency interference suppression. Openings in the tubular shields 45 and 47 are selectively located near the longitudinal ends of the coils to minimize loading of the generated electromagnetic field 24.

[0022] By co-locating the null adjust loop 44, the receive coil 28 and the feedback loop 46 in the coil set 11, the sensitivity of the system 10 near the longitudinal end regions 51 of the coil structure is enhanced. The null adjust loop 44 further includes a plurality of null adjust wire crossover points for shaping the generated electromagnetic field 24. With proper null adjustment, a substantially uniform electromagnetic field, free from weak or "dead" spots, is generated.

[0023] Referring again to FIGURE 2, each detector circuit 30 includes a balun 48 for terminating a corresponding one of the receive coils 28r and 28l. The balun 48 provides a balanced input 50 connected to the ends 52 and 54 of the receive coil 28, thus allowing the receive coils 28 to operate with a relatively high resonant frequency providing increased sensitivity. The balun 48 incorporates input low pass filtering circuitry to provide both electromechanical and radio frequency interference suppression. The balun 48 further converts the balanced input 50 to a single ended, unbalanced termi-

nation 58. The unbalanced signal at termination 58 is applied to a pre-amp circuit 60 that incorporates further low pass filtering and shifts the phase of the unbalanced signal to output a pre-amp signal on line 62. The phase of the pre-amp signal is preferably shifted in comparison to the phase of the two square wave signals 38 and 40 output from the oscillator 14 as needed to provide an all metals response for the detector circuit output.

[0024] The pre-amp output signal on line 62 is applied to a quadrature detector 64 having DC coupled phase 66 and amplitude 68 outputs. The in phase (I) and quadrature phase (Q) square wave signals output from the oscillator 14 are also applied to the quadrature detector 64. Selection of the static operating point for the detector 64 is made by the channel selector 36 with the channel select signal (CS) to match the frequency selected for the generated alternating current electromagnetic field 24. A slight phase adjustment may also be provided by the channel selector 36 to compensate for a response shift in the receive coils 28 when the system 10 is operated on the various selected operating frequencies.

[0025] The DC coupled outputs 66 and 68 are summed at 70, and the dynamic response of the system adjusted at 72 (with respect to the summed amplitude and phase components) to provide a predetermined metal slope response for the receive coil 28. The metal slope response refers to a balancing of the detector circuit 30 operation to detect all metals (both ferrous and non-ferrous) equally well. The adjusted signal output from summer 70 is applied to a low pass filter 74 that filters out high frequency noise components and sets the maximum walk-through rate for metal object detection. This maximum rate allows for typical leg swing velocities.

[0026] Following low pass filtering, the filtered signal output on line 76 is AC coupled to a dual rate high pass filter 78 that includes precision comparators for detecting whether an object is approaching or departing from the passageway 26. If the object is detected as approaching, the filter 78 is set to a slow rate for processing the filtered signal on line 76 and generating a detector output signal on line 79. This allows the system to accurately process slow moving objects. Conversely, if the object is detected as departing, the filter 78 is set to a high rate for processing the filtered signal and generating the detector output signal on line 79. This allows the system to quickly reset for a subsequent object to be processed, thus maximizing the object throughput rate. The circuit diagram for the dual rate, high pass filter 78 is shown in FIGURE 7.

[0027] The processing circuit 32 is connected to receive the detector output signals generated by both detector circuits 30 for the right and left receive coils 28r and 28l, respectively. The processing circuit 32 includes a pair of chained logarithmic amplifier circuits 80 and 82, each one connected to process one of the received detector output signals on lines 79r and 79l. The chained logarithmic amplifier circuits 80 and 82 are implemented

with operational transconductance amplifiers, stabilized with a windowed threshold type comparator. The transconductance amplifiers further provide a multiple-pole, variable low pass filter function that enhances system noise immunity. Each logarithmic amplifier circuit 80 and 82 further includes an auto-zeroing feedback circuit 84 to compensate for thermal drift and background noise. The circuit diagram for one of the logarithmic amplifier circuit 80 and 82 along with auto-zeroing feedback circuit 84 is shown in FIGURE 8.

[0028] When an object moves through the passageway 26 closer to one receive coil 28 than another, the signal derived from the close coil receives a relatively intense and quick processing response from the logarithmic amplifier circuits 80 and 82, while the signal derived from the distant coil receives a relatively weaker and slower response. A weak detector output signal indicative of the detection of a small or distant metal object in the passageway 26 is significantly amplified by the variable low pass filters of the circuits 80 and 82 in accordance with a long integration time constant. Conversely, a strong detector output signal indicative of the detection of a large or close metal object is subjected to a short integration time constant and is only slightly amplified. This selective amplification of the detector output signals is in effect taking the cube root of the output detector signal, and functions to compensate for the known near field inverse cube law attenuation characteristics of the receive coils 28. Thus, the system 10 will possess a wide dynamic range. It will, of course, be understood that in a digital implementation of the processor circuit 32, a precise cube root of the detector output signal will be taken.

[0029] Up to this point, the signals derived by the system from the sensing of the electromagnetic field 24 by the right and left receive coils 28r and 28l, respectively, have been maintained separate from each other. The processing circuit further includes a pair of multiplier circuits 86 and 88. The first multiplier circuit 86 multiplies a cube root signal A output from the logarithmic amplifier 80 by a cube root signal B output from the logarithmic amplifier 82. This signal multiplication operation generates an output signal C in accordance with the following equation:

$$C = (xA) \cdot (yB).$$

Similarly, the second multiplier circuit 88 multiplies the signal A by the signal B. However, the multiplication generates an output signal D in accordance with the following equation:

$$D = (yA) \cdot (xB).$$

The multiplication coefficients x and y in the two above equations are selected empirically as calibration factors.

With correct selection, a predetermined voltage level output at C and D will be achieved regardless of placement of the detected metal object in the field 24.

[0030] The cube root signals A and B output from the logarithmic amplifiers 80 and 82 may be further processed to identify the approximate horizontal location of any detected object. The strength of the signals A and B is related to both the proximity of an object to the receive coils 28r and 28l, respectively, and the metal mass of the object. A dual channel LED bargraph device 85 is connected to outputs from the chained logarithmic amplifiers 80 and 82 and includes a signal strength measuring circuit driven by the output cubed root signals A and B. The higher the strength of the output cubed root signal, the more LEDs in the device 85 that will be lit and the more likely that the detected object is proximate to corresponding receive coil 28'. When the signals are approximately equal, the object is most likely centrally located in the field 24. The bar graph device 85 further includes a display hold circuit for holding LED display of the peak signal strength, thus allowing security personnel to review the location indication provided by the LED display after the person or article has passed through the field 24.

[0031] The multiplication output signals C and D are cross coupled by a pair of difference amplifiers 90 and 92. The first difference amplifier 90 subtracts the output signal D from the output signal C to generate an output signal E in accordance with the following equation:

$$E = 2C - D.$$

Similarly, the second difference amplifier 92 subtracts the output signal C from the output signal D to generate an output signal F in accordance with the following equation:

$$F = 2D - C.$$

[0032] The processing circuit 32 further includes a select circuit 94 that receives the difference output signals E and F from the difference amplifiers 90 and 92, respectively, and outputs a signal G comprising the one of the signals E or F that has the weaker signal level. Thus, if select circuit 94 determines that $E < F$, then signal E will be output from the select circuit as signal G. Conversely, if select circuit 94 determines that $F < E$, then signal F will be output from the select circuit as signal G.

[0033] The output signal G has a signal level indicative of the total mass of metal detected in the electromagnetic field 24. The signal G is applied to one input of a comparator 96, with the other input to the comparator comprising an adjustable signal H generated by a sensitivity threshold circuit 98. If the signal level of the signal G is greater than the signal level of the signal H, then an illicit metal object has been detected, and the

alarm 34 is actuated. By way of the sensitivity threshold circuit 98, the level of the signal H may be adjusted to control the sensitivity of the system 10 and minimize the incidence of undesired metal alarms.

[0034] Reference is now made to FIGURE 4, wherein there is shown a block diagram of a second embodiment of the metal detection system 10' of the present invention. Like the system 10 of FIGURE 1, the second embodiment also utilizes a split field generation coil 12 that is excited in phase by the oscillator 14 to generate a single alternating current electromagnetic field 24 concentrated with substantially uniform field density in the passageway 26.

[0035] In the system 10', however, the electromagnetic field 24 is sensed by a plurality of receive coils 28r' for the right side coil set 11r', and a plurality of receive coils 28l' for the left side coil set 11l'. In the preferred embodiment, six individual receive coils 28'(l) through 28'(6) are disposed in each coil set 11' on either side of the passageway 26. Due to the added system complexity provided by the utilization of twelve receive coils, digital signal processing techniques are preferably used to identify the presence of illicit metal objects in the field. The use of multiple receive coils 28' in each coil set 11' allows for several metal objects in the field 24 to be individually detected and interpolated. This enables the system 10' to differentiate between a single object with a large metal mass and multiple objects with smaller metal masses.

[0036] Each receive coil 28' is connected to a corresponding detector circuit 30' that detects any disturbances in the electromagnetic field 24 sensed by the coils 28'. Each detector circuit 30' is similar in configuration to the detector circuit 30 shown in FIGURES 1 and 2, except that the DC coupled phase 56 and amplitude 68 outputs from the quadrature detector 64 are low pass filtered at 74(1)' and 74(2)', and further processed by a dual signal type, dual rate high pass filter 78' (see, FIGURE 5) that outputs a low pass filtered (at 99(1) and 99(2)) phase 100 and amplitude 102 detection signal from the detector circuit 30'. The high pass filter 78' is further modified to allow a slight DC signal output that is measured by the processing circuitry of the system 10' to determine in a system self-test operation mode if one of the channels is being overloaded. Each of the low pass filters 74(1)' and 74(2)' utilize a single pole low pass filter design. Each of the low pass filters 99(1) and 99(2) utilize a two pole, anti-aliasing low pass filter design. The circuit diagram for the dual signal type, dual rate high pass filter 78' is shown in FIGURE 9.

[0037] The system 10' further includes a multiple channel, twelve bit analog-to-digital converter 104 to convert the plurality of complex analog phase and amplitude detection signals output on lines 100 and 102 from each of the detector circuits 30'. A central processing unit 106 utilizes digital signal processing techniques to process the digitized plurality of detection signals into a digitized image of the object(s) detected in the elec-

tromagnetic field 24. In processing the detection signals, the central processing unit 106 performs similar cubed root, multiplication and differentiation mathematical processes on the detector signals as performed by the processing circuit 32 in the analog system 10 to detect individual object metal mass.

[0038] Each detected object mass is then compared by the processing unit 106 to a predetermined sensitivity threshold to determine if any object has sufficient metal mass to be considered an illicit metal object. For each object so determined, an alarm is sounded and the processor outputs, through the input-output interface 108 for presentation on display 110, a digitized metal image representing the metal mass and metal type of each detected object. Furthermore, the object image is positioned on the display 110 in accordance its approximate detected location within the electromagnetic field 24 to facilitate further investigation by security personnel. The processor 106 further has the capability of overlaying the displayed location of the illicit detected object on an image of a person or article received from a television camera 112 to assist the security personnel in locating the object on the person or article. A control panel 114 is also provided to allow security personnel to control and program operation of the system 10', and a remote interface 115 is provided to allow the system to communicate with external systems such as a security system.

[0039] By appropriately programming the central processing unit 106, the implemented digital signal processing techniques facilitate system 10' operation to ignore the detection of certain types of known objects with relatively large metal masses (e.g., steel toed boots) that typically trigger alarms. Furthermore, test objects may be placed in the field 24 and sampled by the system 10' to program system response to certain objects. Programming of the system 10' may also be implemented through the downloading of object detection (metal mass) data from a disk or via a modem into the central processing unit 106.

[0040] The use of multiple receive coils 28' along with digital signal processing of the detector signals further facilitates the differentiation between objects of different metal types. Thus, the system will operate to distinguish between ferrous and non-ferrous metal objects, and furthermore will distinguish degrees of metal composition (e.g., copper versus silver). This prevents an undesired metal alarm to be caused by the lumping of the ferrous and non-ferrous detections into a single metal mass. The multiple receive coils 28' along with digital signal processing techniques further facilitate the differentiation of metal objects by location within the field 24. This prevents an undesired metal alarm to be caused by the lumping of detections in separate locations into a single metal mass. In combination, these benefits enable the system 10' to determine that no alarm should be signalled when two objects of differing metal types (such as a brass set of keys and a steel lighter) at different locations (in the left and right pockets) are sensed, when

the combination of such sensed metal objects would typically cause an undesired metal alarm.

[0041] The system 10' further includes a identification reader 116 for scanning persons or articles passing through the passageway 26 for an identification code. Such a reader 116 may scan identification cards or bracelets (each recording such a code) carried by persons or attached to articles. Known persons and articles that repeatedly pass through the passageway will be initially scanned and a typical metal pattern resulting from the scan stored by the central processing unit 106 in a file associated with the person's or article's scanned identification code. The next time the person or article passes through the passageway, the identification code is read by the reader 116 and the metal pattern detected by the system 10' is compared by the central processing unit 106 to the typical metal pattern stored for the read code. Detected deviations between the typical and presently sensed metal patterns are then used to identify the presence of illicit metal objects.

[0042] It is preferable that the entire system be implemented digitally. Accordingly, a dual signal type, dual rate high pass filter 78' may be replaced by a high resolution sixteen bit analog-to-digital converter with programmable offsets. Furthermore, a high speed, high resolution analog-to-digital converter may be substituted for nearly all the analog circuitry shown in the detector circuit 30'.

[0043] The split field generation coil 12 in each coil set 11' is preferably comprised of a series connected transmit coil 42', null adjust loop 44', and feedback coil 46'. Reference is now made to FIGURE 6, wherein there is shown the geometry of the coil set 11' of FIGURE 4 positioned on one side of the passageway 26. It will, of course, be understood that a mirror image of the coil geometry illustrated in FIGURE 6 is present in the coil set 11' on the opposite side of the passageway 26.

[0044] The transmit coil 42' for the field generation coil 12 has rounded corners and an elongated rectangular shape having a longitudinal axis 43 of symmetry. The six receive coils 28' (1) through 28' (6) each have an elongated rectangular shape with rounded corners, are coaxially aligned along the axis 43 and oriented coplanar with the transmit coil 42'. The null adjust loop 44' and feedback coil 46' are co-located with the plurality of receive coils 28', and thus are comprised of a corresponding plurality of serially connected sections, each section having a substantially identical size and shape as the corresponding receive coil. Each section of the null adjust loop 44' further includes a plurality of null adjust wire crossover points for shaping the generated electromagnetic field 24.

[0045] The transmit coil 42' is shielded with a resistive Faraday split section tubular shield 45 that is terminated to system ground 49. Each receive coil 28' along with its corresponding section of the feedback coil 46' are gathered together and also shielded with a resistive Faraday split section tubular shield 47' that is terminated to

system 10 ground. Termination of the shields 45 and 47' to system ground provides primary electromechanical interference and radio frequency interference suppression. Openings in the tubular shields 45 and 47' are selectively located near the longitudinal ends of the coils to minimize loading of the generated electromagnetic field 24.

[0046] Reference is now made to FIGURE 7, wherein there is shown a circuit diagram for the dual rate, high pass filter 78 for the system 10 of FIGURES 1 and 2. Resistor R1 and capacitor C1 form the input low pass filter 74 (see FIGURE 2) for filtering the summed amplitude 66 and phase 68 signals output from the quadrature detector 64. The filtered signal is passed through capacitor C2 functioning as a DC blocking high pass filter. The positive (+) and negative (-) inputs to high impedance, low offset operational amplifier U1 are connected to the capacitor C2 through a guarded input 118. The output of the amplifier U1 is also connected to the negative (-) input and to a feedback loop containing resistor R2 connected to the positive (+) input of an operational amplifier U2 configured as a comparator with a slight low pass filtering function. The negative (-) input of the amplifier U2 is connected to ground 120 and to resistor R2 through a capacitor C3. The output of the amplifier U2 is connected to the positive (+) input through a resistor R4, and to a continuation of the feedback loop leading to the control port C of analog switch 122. Port A of the switch 122 is connected to ground 120, and port B of the switch is connected through a resistor R5 to the positive (+) input of the amplifier U1 and to capacitor C2. A resistor R6 is also connected from the positive (+) input of the amplifier U1 and capacitor C2 to ground 120. Resistor R7 functions as a pull-up resistor for the portion of the feedback loop leading to the control port C of analog switch 122. When switch 122 is actuated to port B by the feedback signal at port C, resistor R5 is grounded 120 and the circuit functions in fast rate operational mode described above. Conversely, when the switch 122 is not actuated, resistor R6 controls circuit operation in slow rate operational mode.

[0047] Reference is now made to FIGURE 8, wherein there is shown a circuit diagram for one of the chained logarithmic amplifier circuits 80 or 82 with auto-zeroing 84 for the system 10 of FIGURES 1 and 2. The chained logarithmic amplifier circuit comprises a first logarithmic amplifier circuit 124 implemented with two LM13600N type operational amplifiers and connected to input line 79, a first buffer circuit 126, a second logarithmic amplifier circuit 128 also implemented with two LM13600N type operational amplifiers, and a second buffer circuit 130 outputting to a line 132. Connected to output line 132 is a feedback line 134, with a resistor R8 connecting the feedback line 134 to the negative (-) input of the operational amplifier U3 configured as a comparator. The output of the amplifier U3 is connected to the negative (-) input through a resistor R9. The positive (+) terminal of the amplifier U3 is connected to Vee through a resistor

R10, and to ground 120 through a parallel combination of resistor R11 and capacitor C4. The resistors R10 and R11 function as a voltage divider to set the operating point of the amplifier U3. The capacitor C4 acts as a noise filter. The output of the operational amplifier U3 is connected to a low pass filter circuit 136 comprised of a resistor R12 and a non-polarized electrolytic capacitor C5. The output of the low pass filter circuit 136 is connected to the input line 79 of the chained logarithmic amplifier circuit 80 or 82 through a switch 138 and a resistor R13. The signal output from the low pass filter 136 comprises a square wave that tracks the background and thermal noise passing through the chained logarithmic amplifier circuit 80 or 82. When fed back to the input line 79 of the chained logarithmic amplifier circuit 80 or 82, this noise component is subtracted from the signal. The switch 138 allows the auto-zeroing circuit 84 to be turned off, thus allowing the chained logarithmic amplifier circuit 80 or 82 to be calibrated.

[0048] Reference is now made to FIGURE 9, wherein there is shown a circuit diagram for the dual signal, dual rate, high pass filter 78' for the system 10' of FIGURES 4 and 5. The filter 78' includes both an amplitude input 140 and a phase input 142. The filter 78' is identical to the filter 78 of FIGURE 7, except in the following ways. The filter includes input filter and rate selection circuit for the phase component. Thus, the amplitude and phase inputs 140 and 142 are connected to port A of their respective switches 122a and 122p through voltage dividers 144a and 144p, respectively, comprised of resistors R14 and R15. The voltage dividers 144 allow a little of the DC component of the signals at the amplitude and phase inputs 140 and 142 to reach the amplitude and phase outputs 146 and 148. Furthermore, it will be noted that the switch 122p on the phase side of the filter 78' is not driven by its own comparator, but is rather driven by the feedback output from the amplitude side comparator U2 driving switch 122a.

[0049] Although multiple embodiments of the metal detection system of the present invention have been illustrated in the accompanying Drawings and described in the foregoing Detailed Description, it will be understood that the invention is not limited to the embodiments shown, but is capable of numerous rearrangements, substitutions and modifications without departing from the scope of the invention as defined in the claims.

50 Claims

1. A metal detection system comprising an oscillator (14), a field generation coil (12) connected to and excited by the oscillator to generate an electromagnetic field disrupted by the presence of a metal object therein, an alarm (34) for outputting an alarm indication when a metal mass signal exceeds a threshold signal; **characterized by:**

- a plurality of receiver coils (28) receiving the generated electromagnetic field of the field generation coil (12);
 a plurality of detector circuits (30), each of the detector circuits connected in one-to-one correspondence to each of the receiver coils (28), each detector circuit including means (64, 74, 78) for detecting the disruption of the electromagnetic field received by the corresponding receiver coil and outputting a detection signal indicative thereof; and
 a processor (32) for receiving and processing the detection signals output from the detector circuits to generate a mass signal indicative of the total metal mass of a metal object disrupting the electromagnetic field, the processor (32) comprising a comparator (96) for comparing the mass signal to a threshold signal to actuate the alarm (34) when the mass signal exceeds the threshold signal.
2. The metal detection of Claim 1 further characterized by:
- each of the detector circuits (30) further comprising a balun (48) connected to the corresponding receiver coil, a preamplifier (60) connected to the balun, a quadrature detector (64) connected to the preamplifier and outputting phase and amplitude signals, a summer (70) for adding the phase and amplitude signals, a low pass filter (74) connected to the summer, and a dual rate high pass filter (78) connected to the low pass filter to output the detection signals.
3. The metal detection as in Claim 2 further characterized by:
- the dual rate high pass filter (78) comprising operational amplifiers (U1, U2) responsive to an input signal comprising the phase signal and amplitude signal added by the summer (70) and filtered by the low pass filter (74) for determining when the metal object disrupting the electromagnetic field moves toward or away from the electromagnetic field; and
 a switch (122) responsive to the determination of motion of the metal object for processing the input signal at a first rate when the detected object moves toward the electromagnetic field and processing the input signal at a second rate faster than the first rate when the detected object moves away from the electromagnetic field, the processed input signal output as the detection signal.
4. The metal detection system as in Claim 1 further characterized by:
- the processor (32) comprises logarithmic amplifiers (80, 82) for taking the cube root of each of the detection signals to output corresponding root signals, multipliers (86, 88) for multiplying the root signals to output multiplication signals, difference amplifiers (90, 92) for differentiating the multiplication signals to output differential signals, a select circuit (94) for selecting one of the output differential signals as the mass signal indicative of the total metal mass of the one or more metal objects disrupting the electromagnetic field.
5. The metal detection system as in Claim 4 further characterized by:
- wherein the multiplier (86) multiplies a first root signal (A) by a second root signal (B) to output a first multiplication signal (C) in accordance with the equation $C=(xA)*(yB)$; and
 the multiplier (88) multiplies the first root signal (A) by the second root signal (B) to output a second multiplication signal (D) in accordance with the equation $D=(yA)*(xB)$; and
 wherein xy comprise calibration factors selected to generate substantially the same multiplication signals for detection of a given metal object independent of the location of the object within the electromagnetic field.
6. The metal detection system as in Claim 4 further characterized by:
- wherein the differential amplifier (92) subtracts a first multiplication signal from a multiple of a second multiplication signal to output a first differential signal; and
 wherein the differential amplifier (90) subtracts the second multiplication signal from a multiple of the first multiplication signal to output a second differential signal, the lesser of the first and second differential signals selected by the select circuit (94) as the mass signal.
7. The metal detection system as in Claim 1 further characterized by:
- a central processing unit (106) for processing the detection signals output from the detector circuits to generate a digitized image of each individual metal object detected disrupting the electromagnetic field; and
 a display (110) for displaying the digitized image to display the approximate location of each individual metal object detected disrupting the electromagnetic field.
8. The detection system as in Claim 7 further characterized by:

terized by:

a camera (112) for recording an image of a person or article passing through the passageway; the display (110) displaying the image; and an input output interface (108) for overlaying the digitized image to display the approximate location of each detected individual metal object on a person or in the article.

9. The metal detection system as in Claim 1 further characterized by:

a central processing unit (106) for storing metal mass data of each individual metal object detected disrupting the electromagnetic field for a person or article, for linking the stored metal mass data with an identification number for the person or article, for scanning a person or article passing through the passageway for the assigned identification number, for retrieving the stored metal mass data linked to the scanned identification number, and for comparing the retrieved metal mass data with the individual mass signal indicative of each individual metal object detected disrupting the electromagnetic field.

Patentansprüche

1. Metalldetektionssystem mit einem Oszillator (14), einer Felderzeugungsspule (12), die mit dem Oszillator verbunden ist und durch diesen erregt wird, um ein elektromagnetisches Feld zu erzeugen, das durch die Anwesenheit eines Metallobjektes in diesem gestört wird, einer Alarmvorrichtung (34) zum Ausgeben einer Alarmmeldung, wenn ein Metallmassensignal ein Schwellenwertsignal überschreitet; **gekennzeichnet durch:**

eine Vielzahl von Empfängerspulen (28), die das erzeugte elektromagnetische Feld der Felderzeugungsspule (12) empfangen; eine Vielzahl von Detektorschaltungen (30), wobei jede der Detektorschaltungen in Eins-zu-Eins-Entsprechung mit jeder der Empfängerspulen (28) verbunden ist, wobei jede Detektorschaltung Mittel (64, 74, 78) zum Detektieren der Störung des durch die entsprechende Empfängerspule empfangenen elektromagnetischen Feldes und zum Ausgeben eines dafür charakteristischen Detektionssignals aufweist; und einen Prozessor (32) zum Empfangen und Verarbeiten der von den Detektorschaltungen ausgegebenen Detektionssignale, um ein für die Gesamt-Metallmasse eines das elektromagne-

tische Feld störenden Metallobjektes charakteristisches Massensignal zu erzeugen, wobei der Prozessor (32) einen Komparator (96) zum Vergleichen des Massensignals mit einem Schwellenwertsignal umfasst, um die Alarmvorrichtung (34) auszulösen, wenn das Massensignal das Schwellenwertsignal überschreitet.

2. Metalldetektionssystem nach Anspruch 1, ferner **dadurch gekennzeichnet, dass:**

jede der Detektorschaltungen (30) ferner ein mit der entsprechenden Empfängerspule verbundenes Symmetrierglied (48), einen mit dem Symmetrierglied verbundenen Vorverstärker (60), einen Quadraturdetektor (64), der mit dem Vorverstärker verbunden ist und Phasen- und Amplitudensignale ausgibt, einen Summierer (70) zum Addieren der Phasen- und Amplitudensignale, einen mit dem Summierer verbundenen Tiefpassfilter (74) und einen Zwei-Geschwindigkeits-Hochpassfilter (78) aufweist, der mit dem Tiefpassfilter verbunden ist, um die Detektionssignale auszugeben.

3. Metalldetektionssystem nach Anspruch 2, ferner **dadurch gekennzeichnet, dass:**

der Zwei-Geschwindigkeits-Hochpassfilter (78) Operationsverstärker (U1, U2), die auf ein Eingangssignal reagieren, das das Phasensignal und das Amplitudensignal umfasst, die durch den Summierer (70) addiert und durch den Tiefpassfilter (74) gefiltert wurden, um zu bestimmen, wann das das elektromagnetische Feld störende Metallobjekt sich auf das elektromagnetische Feld zu oder von ihm weg bewegt; und einen auf die Bestimmung der Bewegung des Metallobjektes reagierenden Schalter (122) umfasst, um das Eingangssignal mit einer ersten Geschwindigkeit zu verarbeiten, wenn das detektierte Objekt sich auf das elektromagnetische Feld zu bewegt, und um das Eingangssignal mit einer zweiten Geschwindigkeit zu verarbeiten, die höher als die erste Geschwindigkeit ist, wenn das detektierte Objekt sich von dem elektromagnetischen Feld weg bewegt, wobei das verarbeitete Eingangssignal als das Detektionssignal ausgegeben wird.

4. Metalldetektionssystem nach Anspruch 1, ferner **dadurch gekennzeichnet, dass:**

der Prozessor (32) logarithmische Verstärker (80, 82) zum Bestimmen der Kubikwurzel von jedem der Detektionssignale, um entsprechen-

- de Wurzelsignale auszugeben, Multiplizierer (86, 88) zum Multiplizieren der Wurzelsignale, um Multiplikationssignale auszugeben, Differenzverstärker (90, 92) zum Differenzieren der Multiplikationssignale, um Differenzsignale auszugeben, und eine Auswahlschaltung (94) umfasst, um eines der Ausgangs-Differenzsignale als das Massensignal auszuwählen, das für die Gesamt-Metallmasse des einen oder der mehreren Metallobjekte charakteristisch ist, das bzw. die das elektromagnetische Feld stört bzw. stören.
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55
- de der Multiplizierer (86) ein erstes Wurzelsignal (A) mit einem zweiten Wurzelsignal (B) multipliziert, um ein erstes Multiplikationssignal (C) gemäß der Gleichung $C=(xA)*(yB)$ auszugeben; und
 der Multiplizierer (88) das erste Wurzelsignal (A) mit dem zweiten Wurzelsignal (B) multipliziert, um ein zweites Multiplikationssignal (D) gemäß der Gleichung $D=(yA)*(xB)$ auszugeben; und
- wobei xy Kalibrationsfaktoren umfassen, die ausgewählt sind, um im Wesentlichen dieselben Multiplikationssignale zur Detektion eines gegebenen Metallobjektes zu erzeugen, unabhängig von dem Ort des Objektes innerhalb des elektromagnetischen Feldes.
6. Metalldetektionssystem nach Anspruch 4, ferner **dadurch gekennzeichnet, dass:**
- der Differenzverstärker (92) ein erstes Multiplikationssignal von einem Vielfachen eines zweiten Multiplikationssignales subtrahiert, um ein erstes Differenzsignal auszugeben; und
 der Differenzverstärker (90) das zweite Multiplikationssignal von einem Vielfachen des ersten Multiplikationssignales subtrahiert, um ein zweites Differenzsignal auszugeben, wobei das kleinere des ersten und des zweiten Differenzsignals durch die Auswahlschaltung (94) als das Massensignal ausgewählt wird.
7. Metalldetektionssystem nach Anspruch 1, ferner **gekennzeichnet durch:**
- eine zentrale Recheneinheit (106) zum Verarbeiten der von den Detektorschaltungen ausgegebenen Detektionssignale, um ein digitalisiertes Bild jedes einzelnen Metallobjektes zu erzeugen, das beim Stören des elektromagnetischen Feldes detektiert wird; und
- eine Anzeige (110) zum Anzeigen des digitalisierten Bildes, um den ungefähren Ort jedes einzelnen Metallobjektes anzuzeigen, das beim Stören des elektromagnetischen Feldes detektiert wird.
8. Detektionssystem nach Anspruch 7, ferner **gekennzeichnet durch:**
- eine Kamera (112) zum Aufnehmen eines Bildes einer Person oder eines Artikels, die bzw. der sich **durch** den Durchgang bewegt; die Anzeige (110), die das Bild anzeigt; und
 eine Eingabe-Ausgabe-Schnittstelle (108) zum Überlagern des digitalisierten Bildes, um den ungefähren Ort jedes detektierten einzelnen Metallobjektes an einer Person oder in dem Artikel anzuzeigen.
9. Metalldetektionssystem nach Anspruch 1, ferner **gekennzeichnet durch:**
- eine zentrale Recheneinheit (106) zum Speichern von Metallmassen-Daten jedes einzelnen beim Stören des elektromagnetischen Feldes detektierten Metallobjektes für eine Person oder einen Artikel, zum Verknüpfen der gespeicherten Metallmassen-Daten mit einer Identifikationsnummer für die Person oder den Artikel, zum Abtasten einer Person oder eines Artikels, die bzw. der sich **durch** den Durchgang bewegt, nach der zugewiesenen Identifikationsnummer, zum Abrufen der mit der abgetasteten Identifikationsnummer verknüpften gespeicherten Metallmassen-Daten und zum Vergleichen der abgerufenen Metallmassen-Daten mit dem individuellen Massensignal, das für jedes einzelne beim Stören des elektromagnetischen Feldes detektierte Metallobjekt charakteristisch ist.

Revendications

1. Système de détection de métaux comprenant un oscillateur (14), une bobine de génération de champ (12) connectée à l'oscillateur et excitée par celui-ci pour générer un champ électromagnétique perturbé par la présence d'un objet métallique à l'intérieur de celui-ci, une alarme (34) pour produire une indication d'alarme lorsqu'un signal de masse de métal dépasse un signal de seuil ; **caractérisé par :**

une pluralité de bobines de réception (28), recevant le champ électromagnétique généré de la bobine de génération de champ (12) ;
 une pluralité de circuits de détection (30), cha-

cun des circuits de détection étant connecté selon une correspondance bi-univoque à chacune des bobines de réception (28), chaque circuit de détection comprenant des moyens (64, 74, 78) pour détecter la perturbation du champ magnétique reçu par la bobine de réception correspondante et produire un signal de détection indiquant cette perturbation ; et un processeur (32) pour recevoir et traiter les signaux de détection produits par les circuits de détection pour générer un signal de masse indiquant la masse de métal totale d'un objet métallique perturbant le champ magnétique, le processeur (32) comprenant un comparateur (96) pour comparer le signal de masse à un signal de seuil afin d'activer l'alarme (34) lorsque le signal de masse dépasse le signal de seuil.

2. Système de détection de métaux selon la revendication 1, **caractérisé en outre en ce que :**

chacun des circuits de détection (30) comprend par ailleurs un symétriseur (48) connecté à la bobine de réception correspondante, un préamplificateur (60) connecté au symétriseur, un détecteur en quadrature de phase (64) accouplé au préamplificateur et produisant des signaux de phase et d'amplitude, un sommateur (70) pour ajouter les signaux de phase et d'amplitude, un filtre passe-bas (74) connecté au sommateur et un filtre passe-haut à deux débits (78) connecté au filtre passe-bas pour transmettre les signaux de détection.

3. Système de détection de métaux selon la revendication 2, **caractérisé en outre en ce que :**

le filtre passe-haut à deux débits (78) comprend des amplificateurs opérationnels (U1, U2) réagissant à un signal d'entrée comprenant le signal de phase et le signal d'amplitude ajoutés par le sommateur (70) et filtrés par le filtre passe-bas (74) pour déterminer le moment où l'objet métallique perturbant le champ magnétique se rapproche ou s'écarte du champ magnétique ; et un commutateur (122) réagissant à la détermination du mouvement de l'objet métallique pour le traitement du signal d'entrée à un premier débit lorsque l'objet détecté se déplace vers le champ électromagnétique et le traitement du signal d'entrée à un second débit plus rapide que le premier débit lorsque l'objet détecté s'écarte du champ magnétique, le signal d'entrée traité étant produit en tant que signal de détection.

4. Système de détection de métaux selon la revendication 1, **caractérisé en outre en ce que :**

cation 1, **caractérisé en outre en ce que :**

le processeur (32) comprend des amplificateurs logarithmiques (80, 82) pour prendre la racine carrée des signaux de détection pour obtenir des signaux de racine correspondants, des multiplicateurs (86, 88) pour multiplier les signaux de racine pour obtenir des signaux de multiplication, des amplificateurs différentiels (90, 92) pour différencier les signaux de multiplication afin d'obtenir des signaux différentiels, un circuit de sélection (94) pour sélectionner l'un des signaux différentiels obtenus en tant que signal de masse indiquant la masse de métal totale du ou des objets métalliques perturbant le champ magnétique.

5. Système de détection de métaux selon la revendication 4, **caractérisé en outre en ce que :**

le multiplicateur (86) multiplie un premier signal de racine (A) par un second signal de racine (B) pour obtenir un premier signal de multiplication (C) selon l'équation $C=(xA)*(yB)$; et le multiplicateur (88) multiplie le premier signal de racine (A) par le second signal de racine (B) pour obtenir un second signal de multiplication (D) selon l'équation $D=(yA)*(xB)$; et xy comprennent des facteurs d'étalonnage sélectionnés pour générer sensiblement les mêmes signaux de multiplication pour la détection d'un objet métallique donné indépendant de l'emplacement de l'objet à l'intérieur du champ électromagnétique.

6. Système de détection de métaux selon la revendication 4, **caractérisé en outre en ce que :**

l'amplificateur différentiel (92) soustrait un premier signal de multiplication d'un multiple d'un second signal de multiplication pour obtenir un premier signal différentiel ; et l'amplificateur différentiel (90) soustrait le second signal de multiplication d'un multiple du premier signal de multiplication pour obtenir un second signal différentiel, le plus petit des premier et second signaux différentiels sélectionné par le circuit de sélection (94) étant le signal de masse.

7. Système de détection de métaux selon la revendication 1, **caractérisé en outre par :**

une unité centrale (106) pour traiter les signaux de détection produits par les circuits de détection pour générer une image numérisée de chaque objet métallique individuel détecté perturbant le champ magnétique ; et

une unité d'affichage (110) pour afficher l'image numérisée afin de visualiser l'emplacement approximatif de chaque objet métallique individuel détecté perturbant le champ magnétique.

5

8. Système de détection selon la revendication 7, caractérisé en outre par :

une caméra (112) pour enregistrer une image d'une personne ou d'un article passant à travers le passage ;
l'unité d'affichage (110) pour afficher l'image ;
et
une interface d'entrée sortie (108) pour superposer l'image numérisée pour afficher l'emplacement approximatif de chaque objet métallique individuel détecté sur une personne ou dans l'article.

10

15

9. Système de détection de métaux selon la revendication 1, caractérisé en outre par :

20

une unité centrale (106) pour stocker des données de masse de métal de chaque objet métallique individuel détecté perturbant le champ magnétique pour une personne ou un article, pour associer les données de masse de métal stockées à un numéro d'identification correspondant à la personne ou l'article, pour balayer une personne ou un article passant à travers le passage pour le numéro d'identification affecté, pour récupérer les données de masse de métal stockées associées au numéro d'identification balayé et pour comparer les données de masse de métal récupérées au signal de masse individuel indiquant chaque objet métallique individuel détecté perturbant le champ magnétique.

25

30

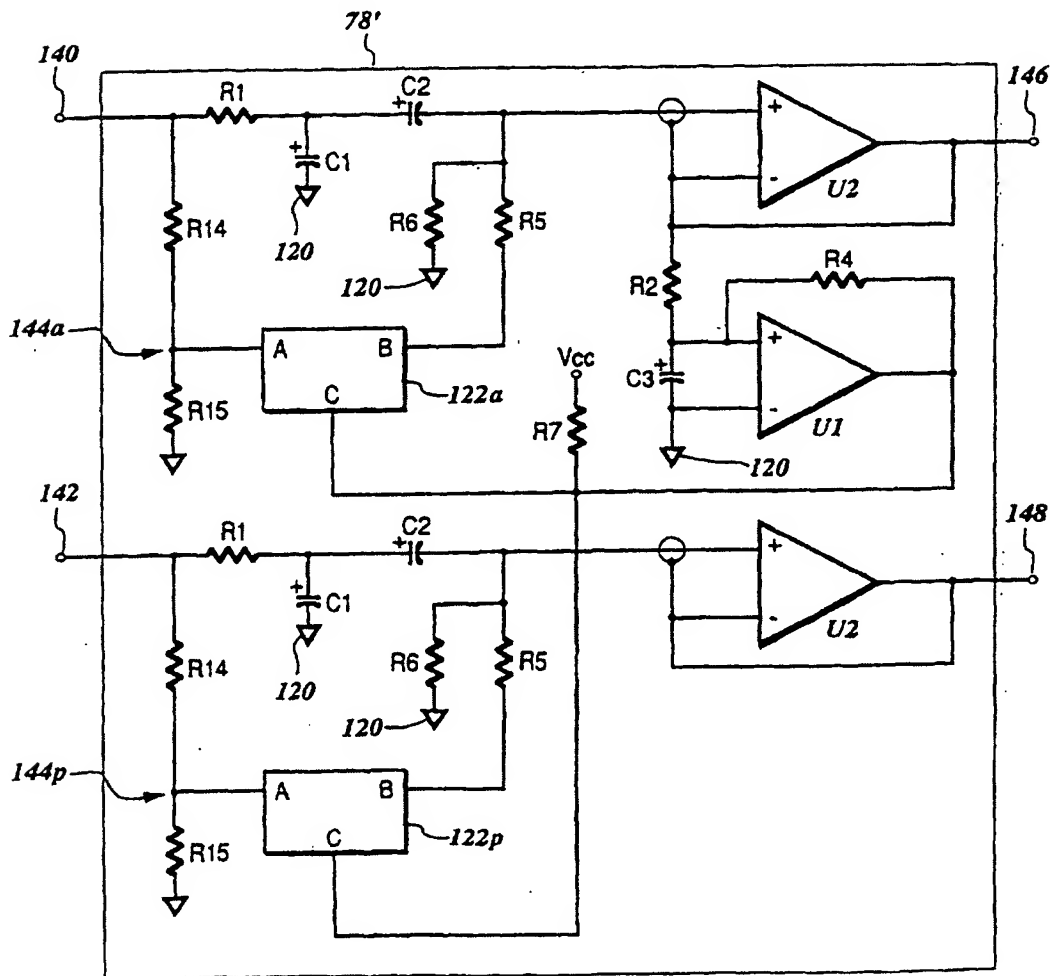
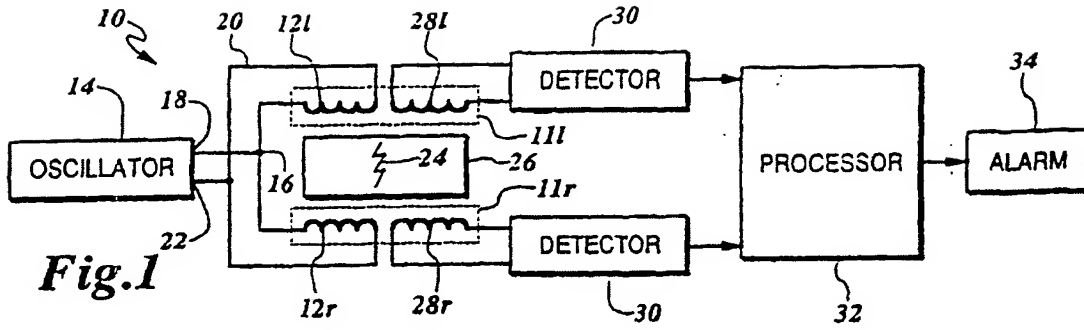
35

40

45

50

55



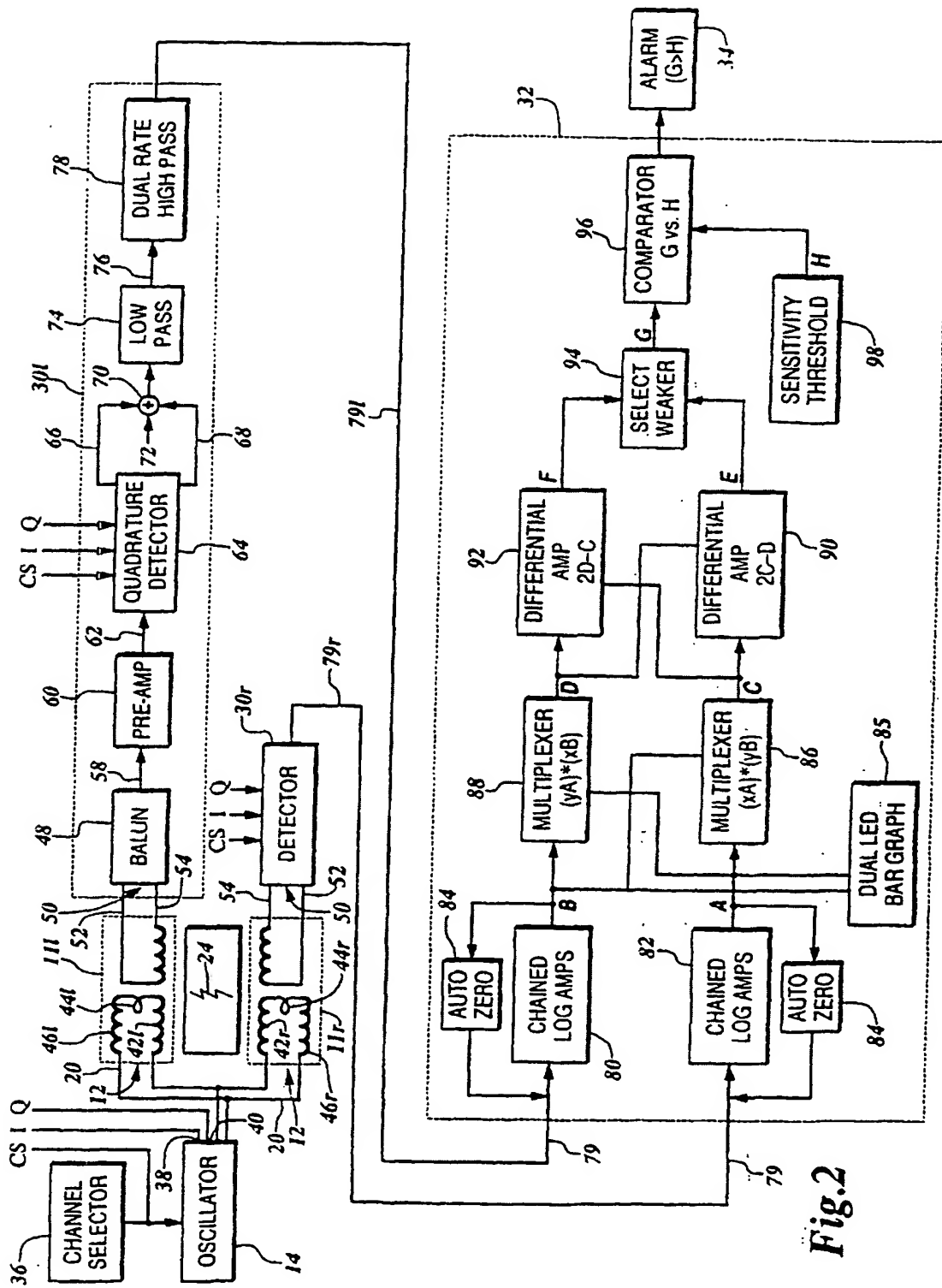


Fig.2

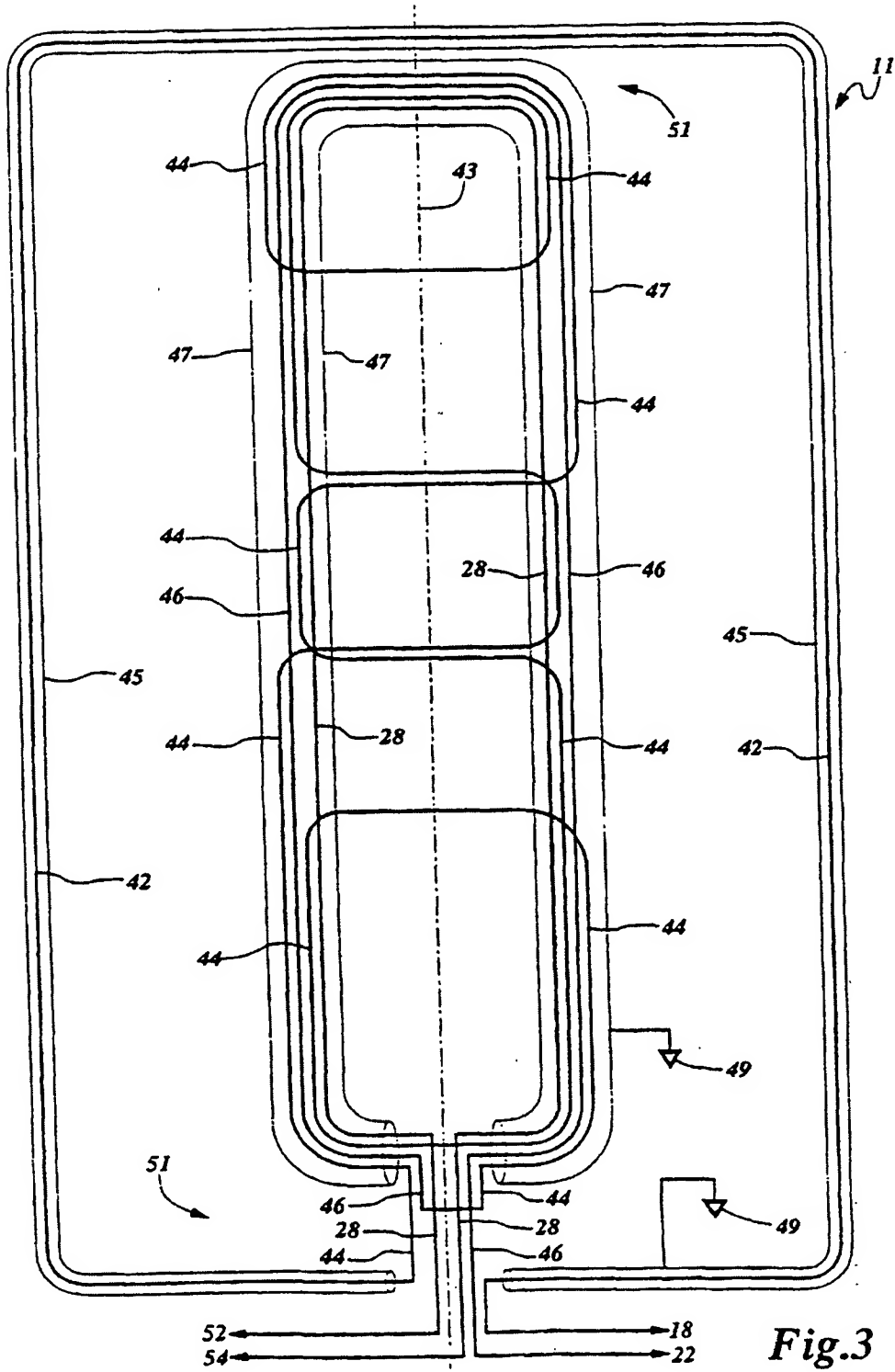
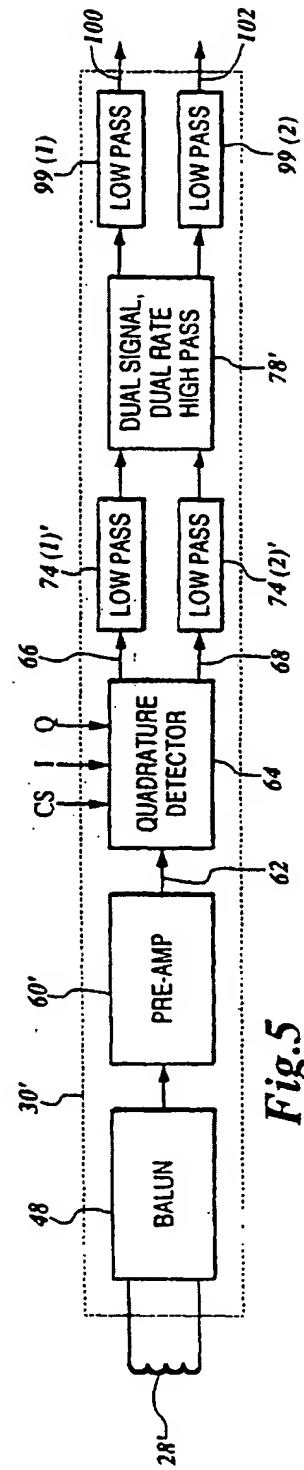
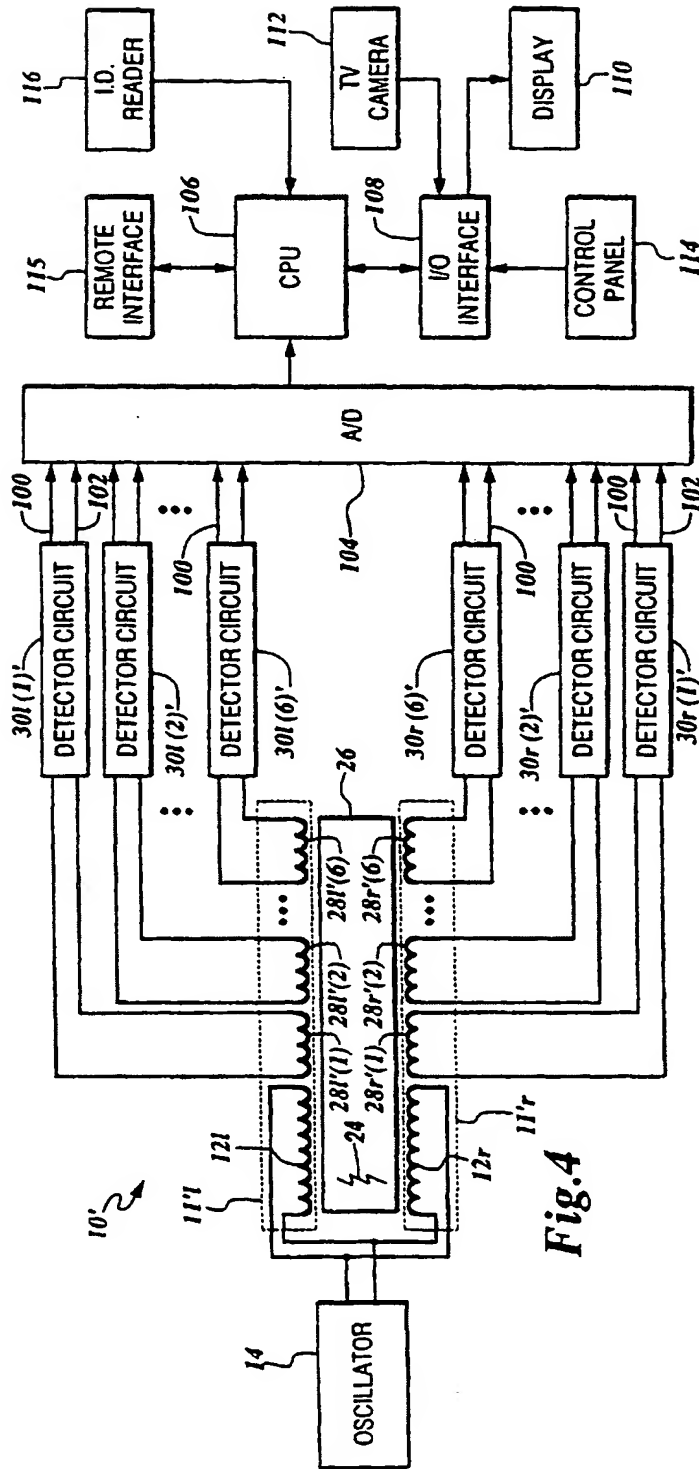
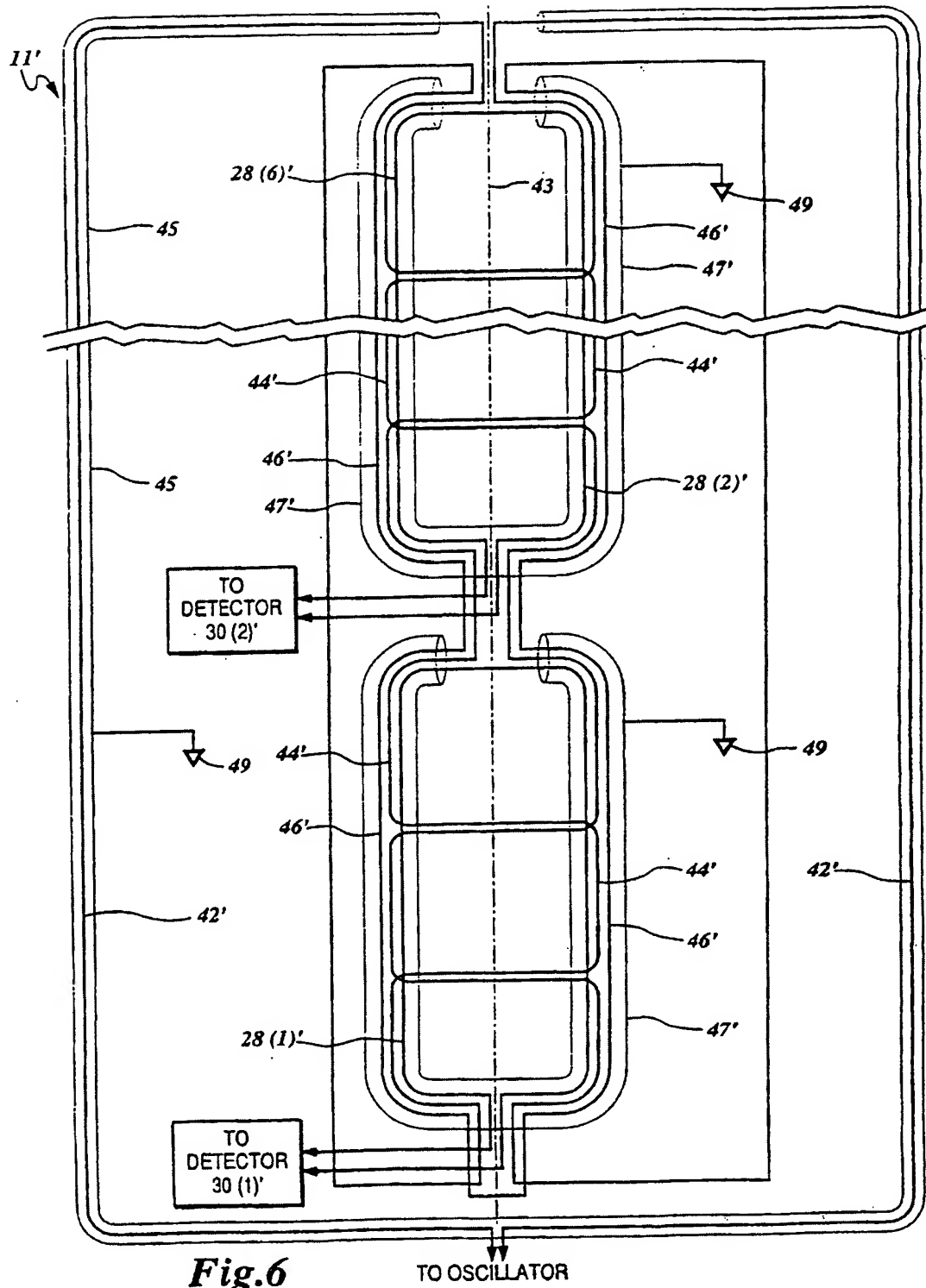


Fig.3





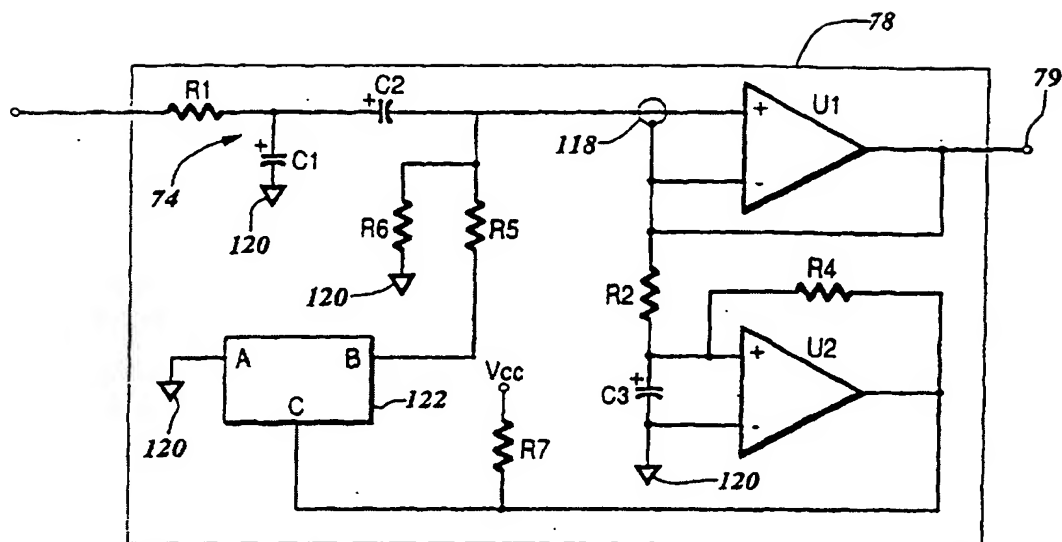
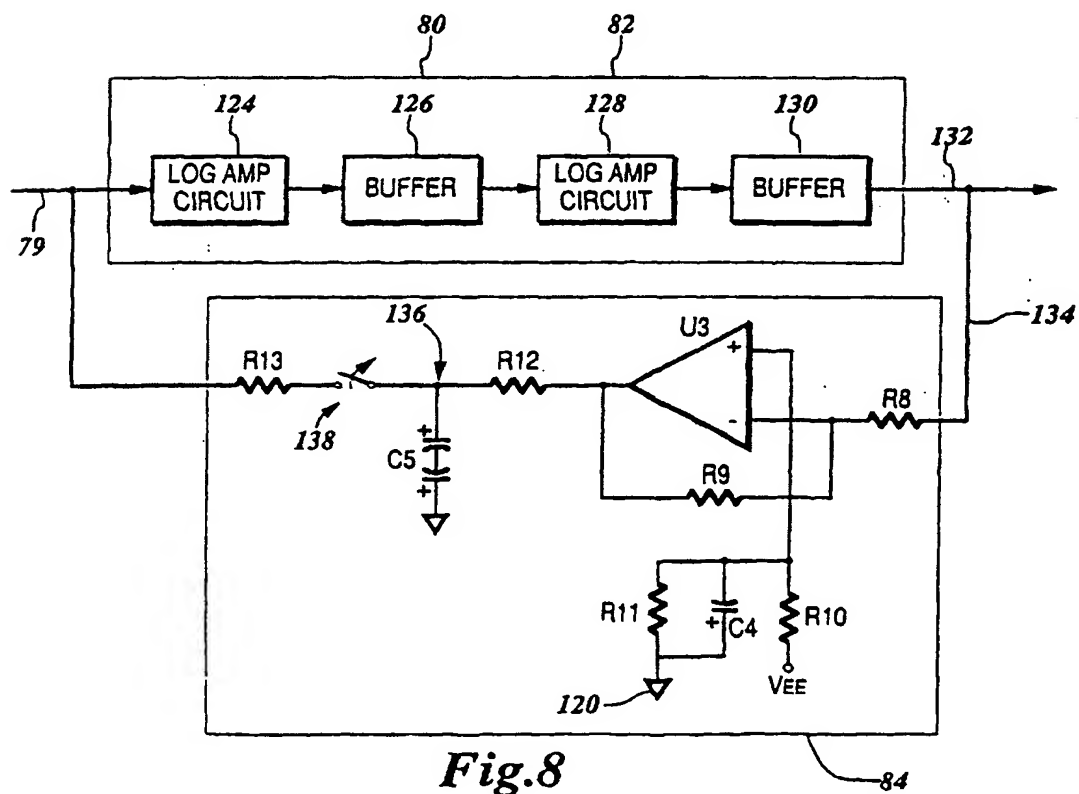


Fig.7



THIS PAGE BLANK (11/18/70)

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☒ FADED TEXT OR DRAWING
- ☒ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☐ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☐ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☐ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.

THIS PAGE BLANK (USPTO)